KTDA Tea Factories

Thermal Manual®

2019

Presentation Outline

1. Introduction
2. Firewood Management
3. Boilers and Steam Systems
4. Production Floor Machinery Operations & Maintenance
5. Health and Safety

Target Group

- Plant Technicians
- Mechanics and
- Boiler Operators

MOD 1: INTRODUCTION

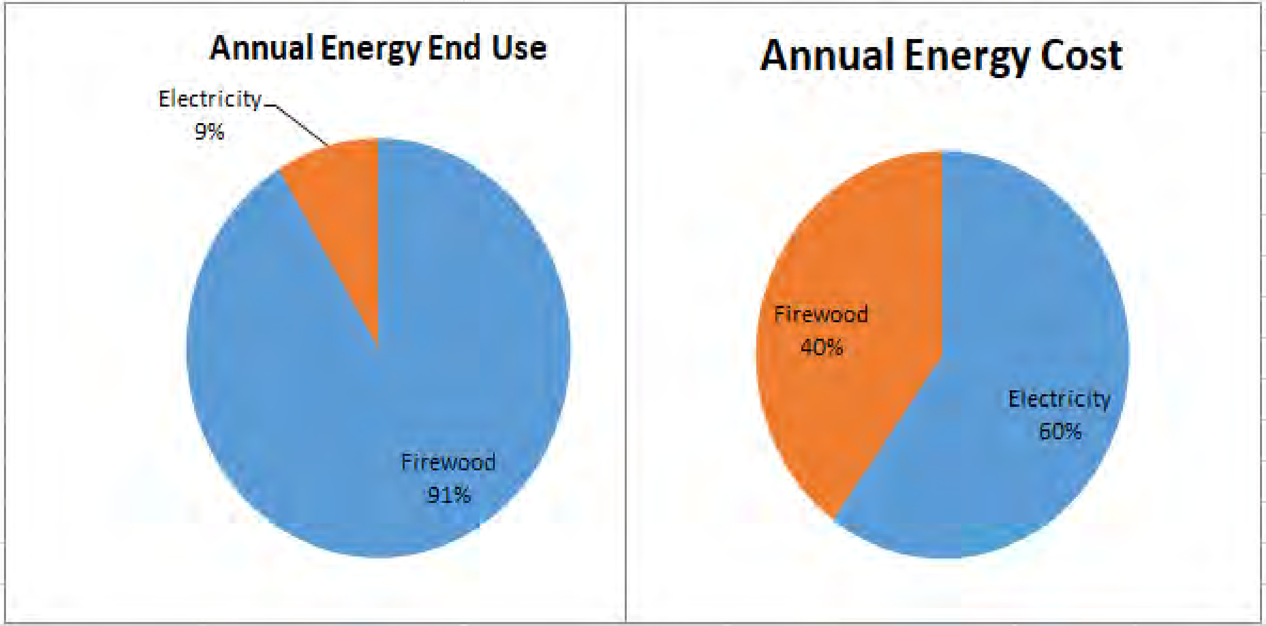
Why Energy Efficiency

1. High cost of energy and production: 25% cost of producing black CTC teas.
2. Shortage of wood fuel: Logging ban by Govt of Kenya
3. Environmental protection: Reduce greenhouse gases and mitigate global warming
4. Legal requirement: Energy Management Regulations 2012

Key Figures for KTDA managed factories

- Entire KTDA (69 factories) annual firewood consumption is 900,000 m3 (1,575,000,000.00 kWh) while electricity is 150,000,000 kWh.
- Cost of electricity -KSh18 /kWh while cost of firewood is Kshs 2000/m3
- Annual energy bill about KSh. 4.5 billion, firewood is KSh1.8 billion whereas electricity is KSh 2.7 billion
- 600,000 farmers (families)
- 10,000 direct jobs

Energy End Use and Cost



- 1 kWh of energy = 3.6MJ (*whether thermal or electrical*)
- Electricity costlier than firewood
- 1 kWh of electricity=KSh 18 while 1 kWh of firewood= KSh 1.14

Role of Plant Technicians

- Maintenance of machinery to sustain efficiency
- Support operations to improve energy efficiency
- Training and awareness creation: As members of the energy committee.
- Ensure safe working environment

Sources of Thermal Energy

Wood logs

Tree stamps

Furnace Oil

Macadamia nut shells

Briquettes

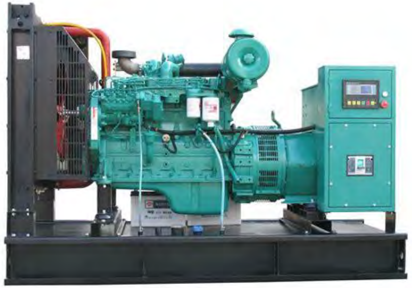
Solar Water heaters

Sources of Electricity

1. Kenya Power- Grid electricity

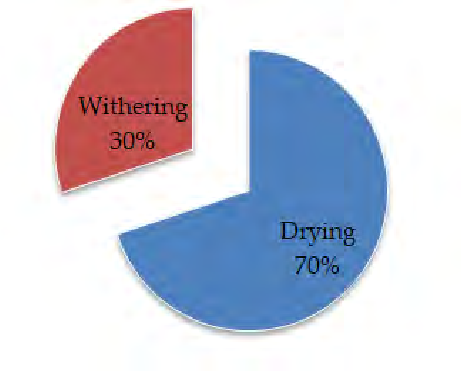
2. KTDA Power – 50% of factories to be connected

3. Diesel Generators: backup electricity

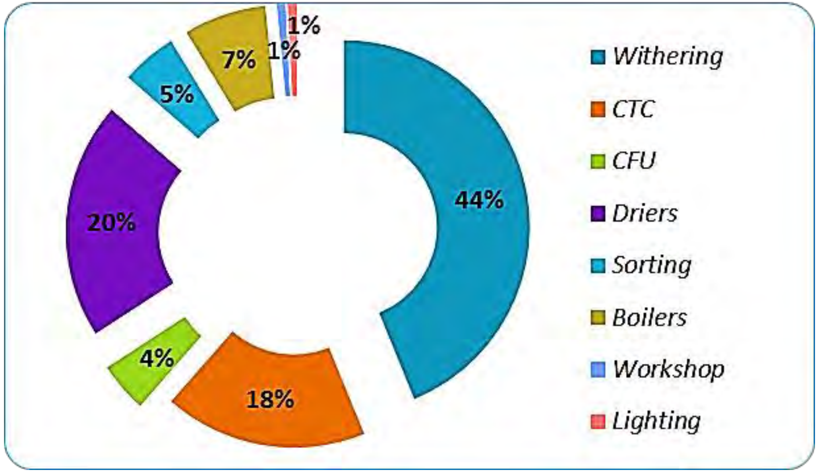


Where is energy used in factories

1. Steam : 60-70% drying, 30-40% withering



2. Electricity



MOD 2: Wood fuel Management

- A 3 line factory **[15 million Kg.GL/year; 23% OT; 300kgMT/m³]** uses **11,500m³/year** of firewood

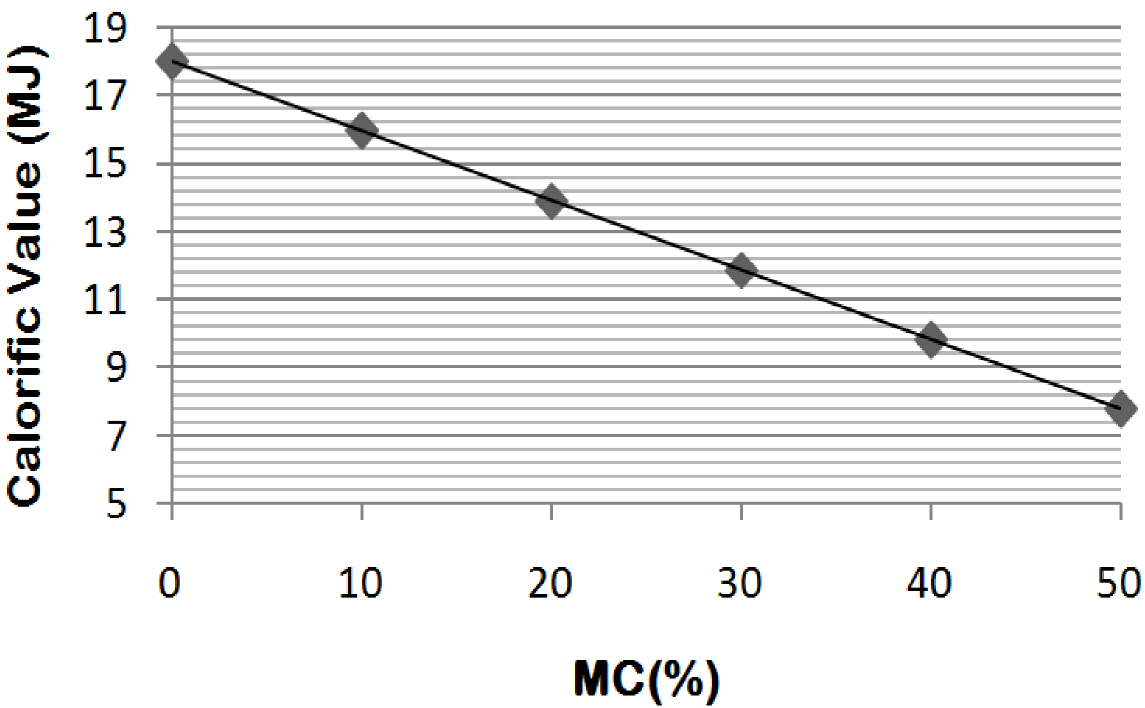
Made Tea = (23×15,000000)/100
= 3,450,000 Kg.MT/year
FUI= 300 Kg.MT/m3 therefore
Firewood Consumed= 3,450,000
Kg.MT/(300Kg.MT/m3)
=11,500 m3/year
Similar case FUI of 250 Kg.MT/m3,
firewood consumption will be ??
=13,800 m3/year
Firewood Cost difference= (13800-
11500)m3×2000 Kshs/m3
= Kshs 460,000

One mature tree produces 1.0 m3 of quality firewood. Therefore one factory consumes 11,500 trees/year.

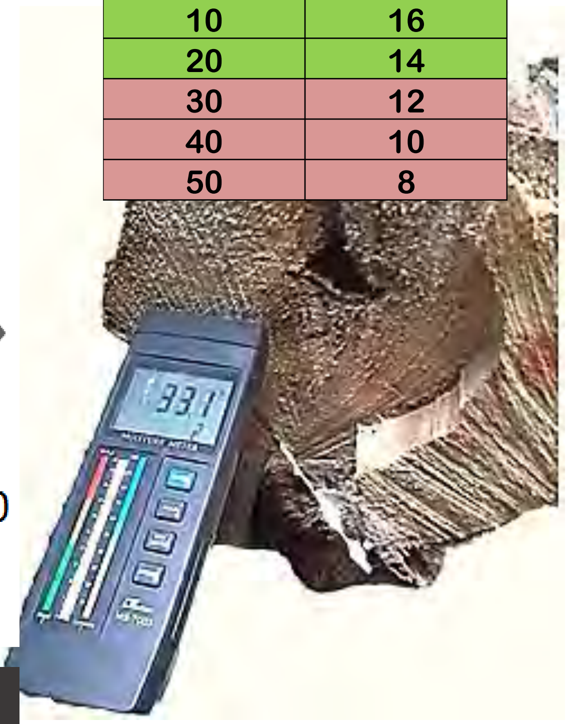
Wood fuel management

- Factories have established wood fuel plantations but will not meet the entire demand – 20,000 acres
- The best age for harvesting wood is from 8 years and above : Why 8 years? Discuss with Trainees
- An acre has about 700 trees. For a factory consuming 70m3 per day it will require 3 acres/month and 36 acres/year.

Moisture Content vs. Calorific Value



MC(%)	CV
0	18
10	16
20	14
30	12
40	10
50	8



The higher the MC the lower the CV; more firewood consumption

Firewood Seasoning-Sheds

- **Reduce M.C. through seasoning and keeping out rain**

1. Heavy gauge anti-UV polythene

- More heat penetration
- Easy and faster to replace if damaged
- Good air circulation
- Cheaper than iron sheet

Consider heavy gauge polythene shed when expanding capacity.

Firewood Sheds

2. Iron sheets + translucent sheets

Common shades in many factories

❖ Less heat penetration (reflective property of iron sheets)

❖ Time involving to repair if damaged

❖ Instances of air condensation due to poor air circulation

❖ Costlier than polythene sheet

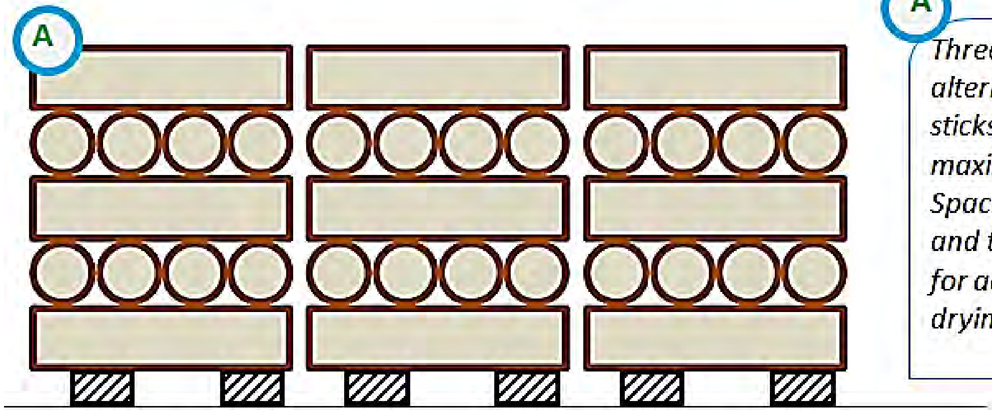
Firewood Sheds

3. Translucent sheets

Less common in KTDA factories

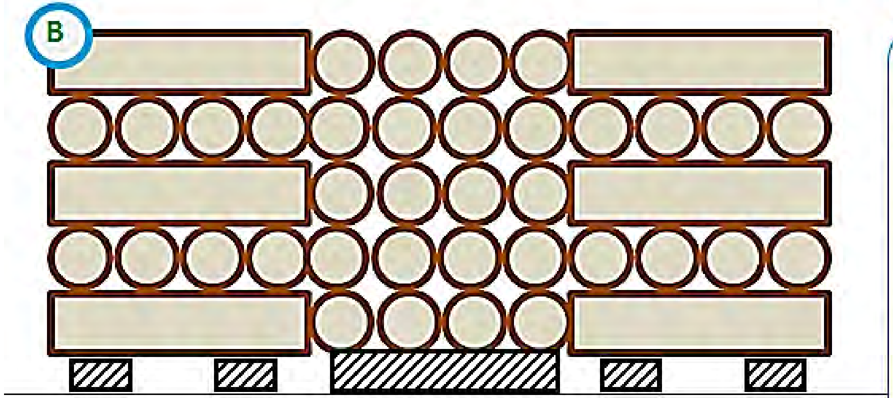
- ❖ More heat penetration as compared to Iron sheets
- ❖ Needs regular cleaning to remove dirt and improve transparency
- ❖ Costly to set up; compared to polythene.

Firewood Stacking



A

Three tower system with alternate cigarettes sticks stacking for maximum stability. Spaces between the logs and the towers allows for aeration and even drying of the firewood.



B

Two tower stacking method with cigarette sticks stacking in between the two towers to avoid roll over of the logs. Cigarette sticks stacking allow for maximum space utilization but needs more drying time.

Best Practices In Firewood Management

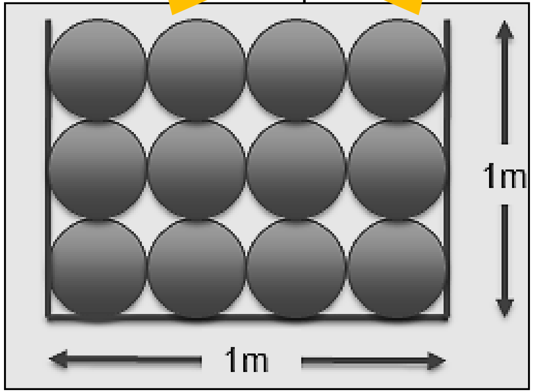
- Use of mature wood varieties
- Adequate seasoning of wood; target 20% to 25%
  - FIFO
  - Access routes clear
  - Procure pre-seasoned wood
- Prevent wood re-wetting
  - Roof cover
  - Floor quality
  - Storm water drainage
- Stack properly to allow air flow during seasoning
- Split wood before stacking (faster seasoning)

Bad Practices In Firewood Management

- Not draining firewood sheds
- Leaving dry wood in the rain
- Feeding wet wood to boiler
- Billeting thin logs – unnecessary saw dust, waste of labour and power

Wood Measurement

You
can't manage
what isn't
measured.
If you don't
measure, you
can't improve it

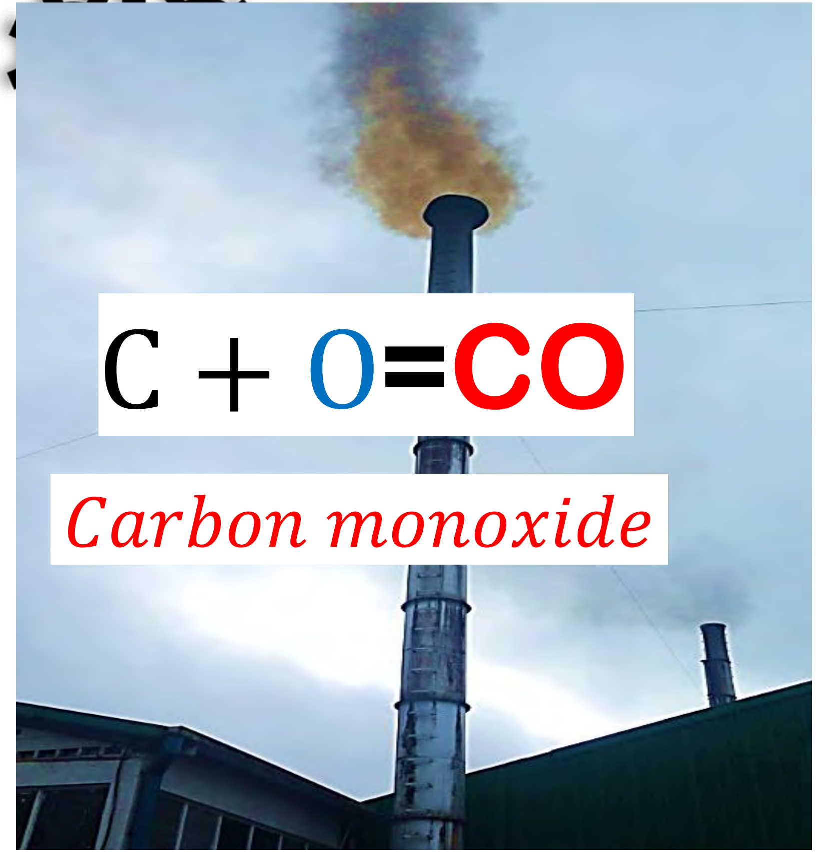


Correct (More Dense)
Density: 493kg/m³
Calorific: 14MJ/Kg
At 20% MC
Energy: 6902MJ

Wrong (Less dense)
Density: 394kg/m³
Calorific: 14MJ/Kg
At 20% MC
Energy: 5516MJ

Use firewood with the highest density for more C.V (Energy)

Environmental Impact

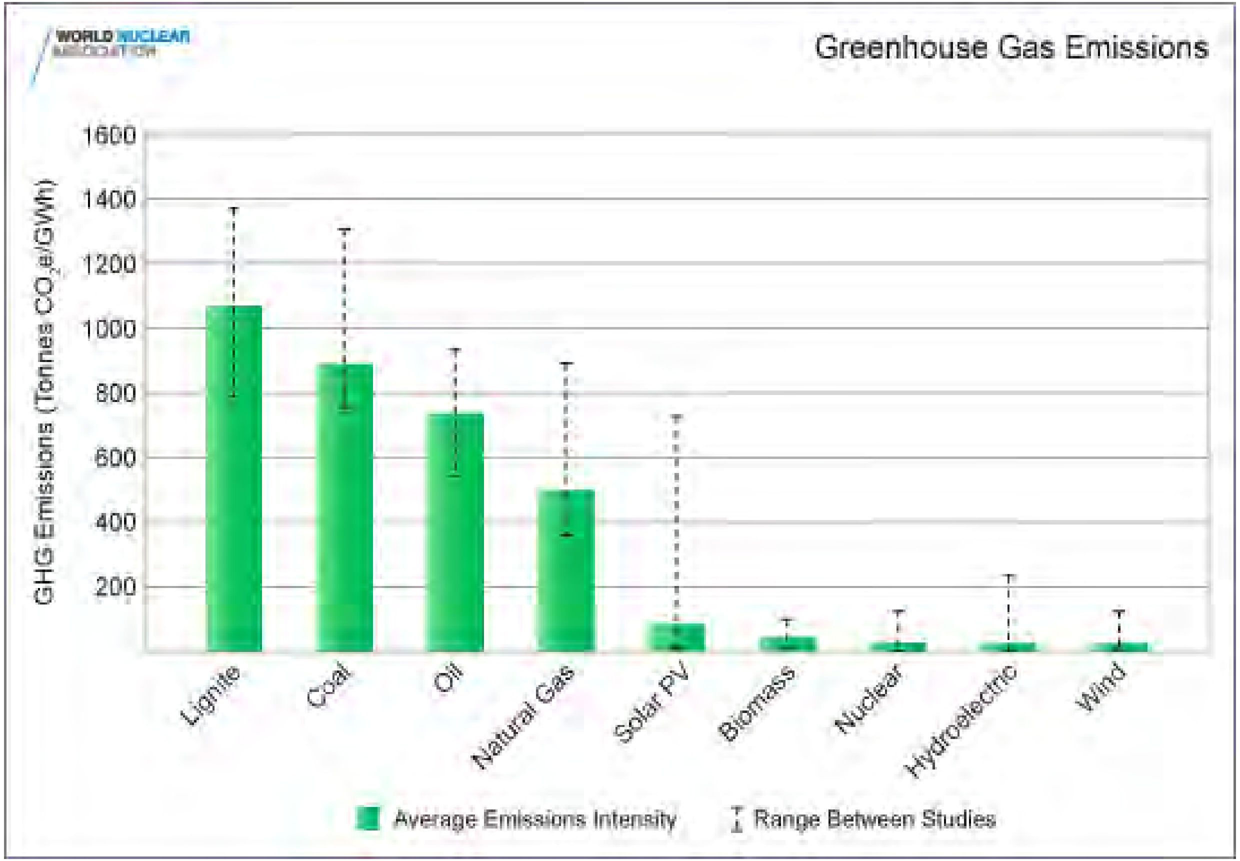


- The combustion efficiency while burning wood for the production of heat energy is crucial to avoid emission of **Carbon Monoxide** and un-burnt particulates to the atmosphere.
- The air pollution caused by discharging this kind of flue gases causes asthma & related diseases.
- Trees harvesting leads to soil erosion
- Deforestation by tree harvesting impacts on climate

Green House Gas (GHG) Emissions

- GHG emission contributes to global warming
- CO_{2eq} considers total emission from all green house gases
- Green house gases include CO_2, CH_4, NO_x, CFC.
- Coal emits more GHG than oil.
- Biomass (firewood) GHG emission lower than oil.
- Hydroelectric & wind emit the least (clean energy)
- KTDA commits to reduction of carbon footprint – environmental protection by:

1. Reducing electricity use &
2. Reducing diesel, FO and biomass (thermal energy) in the production process
3. Generating energy from clean energy sources e.g. hydro, solar



MOD 3 : Boilers and Steam System

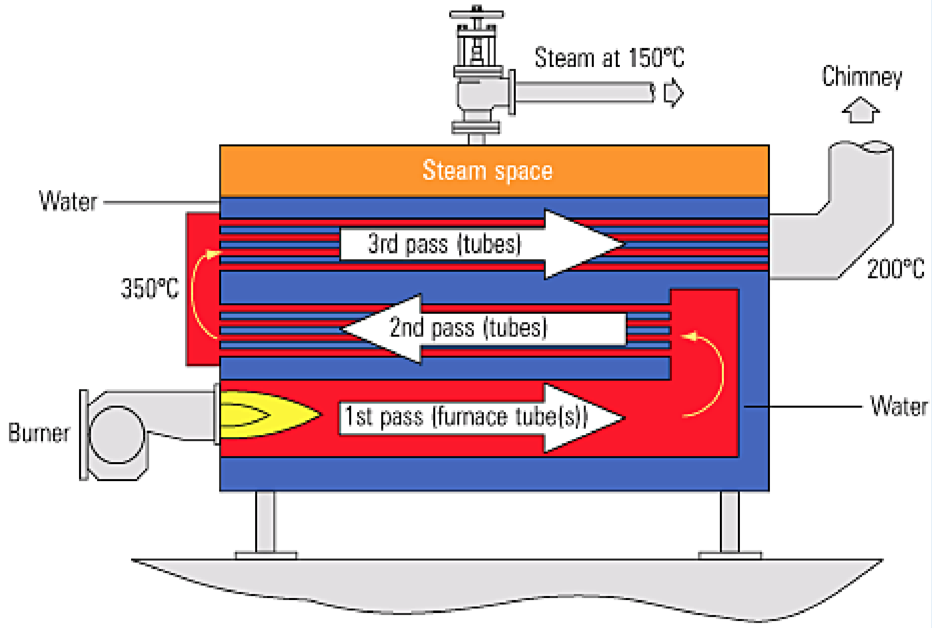
Classification of Steam Boilers

- Stationary boilers (power plant, industrial, centralized heating, combined heat and power (CHP) or portable boilers (marine, Locomotive)
- Vertical or horizontal boilers: depending on orientation
- Solid, liquid or gas fired boilers
- Fire (Smoke) tube boiler: water is outside tubes while the hot gases are inside tubes or
- Water tube boiler: contains large number of small tubes through which water circulates, the fire and hot gases being outside of the tubes e.g. High Pressure in CHP plants

Boiler and Steam System

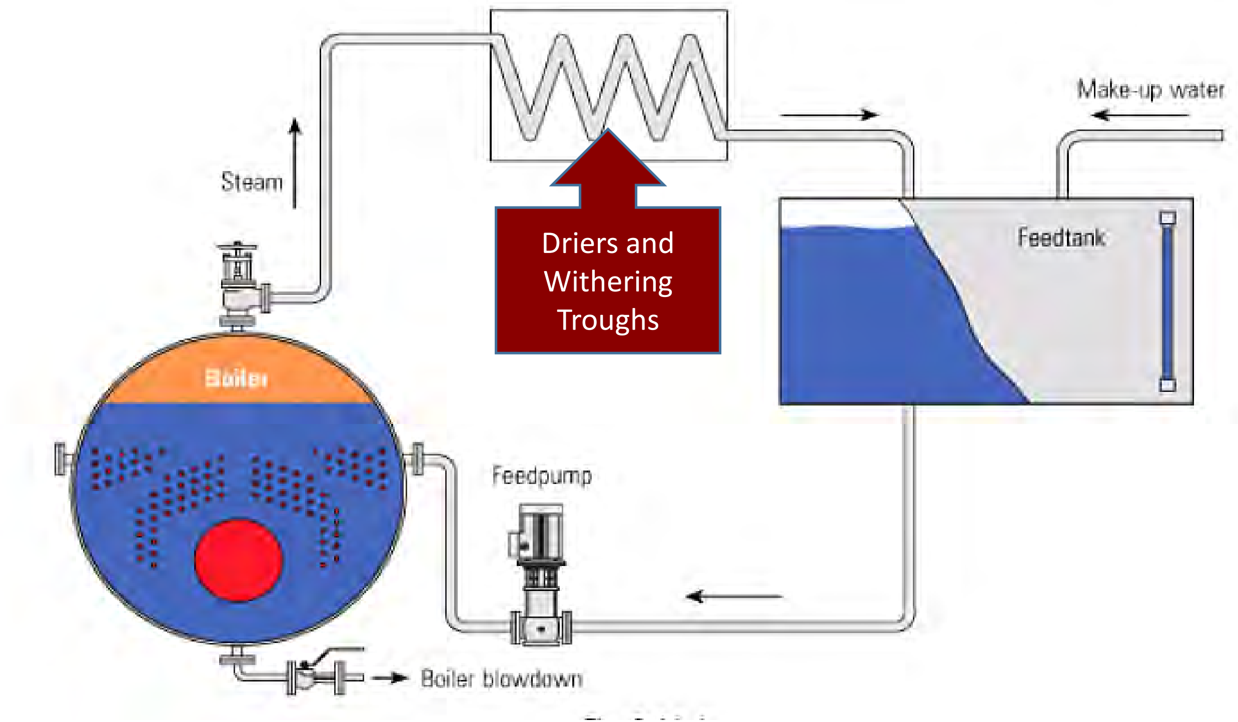
Boilers in KTDA factories can be classified as:

1. Horizontal
2. Stationary
3. Solid fired (previously liquid fired)
4. Fire (smoke) tube



- ❖ Maximum heat transfer in 3 pass fire (smoke) tube boiler .
- ❖ Boiler generates steam at 8-10 bars.

Boilers and Steam System



- Thermal energy in steam critical in tea processing
- Steam consumed in Drying and Withering processes
- Required steam pressure at dryers radiators is 8 bar while at the withering trough radiators is 4 bar.

Energy Conversion Factors

- Electricity 1KWH=3.6MJ
- Fuel Oil = 40.28 MJ/Litre
- Firewood 1 m^3 = 5170 MJ => 1800 Kgs of steam/m^3
- Bagasse 50% mc 1 Kg=7.5 MJ
- Bagasse 30% mc 1 Kg=12.6 MJ
- Coffee Husks 1 Kg=15.1 MJ

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Key Thermal Energy Performance Indicators

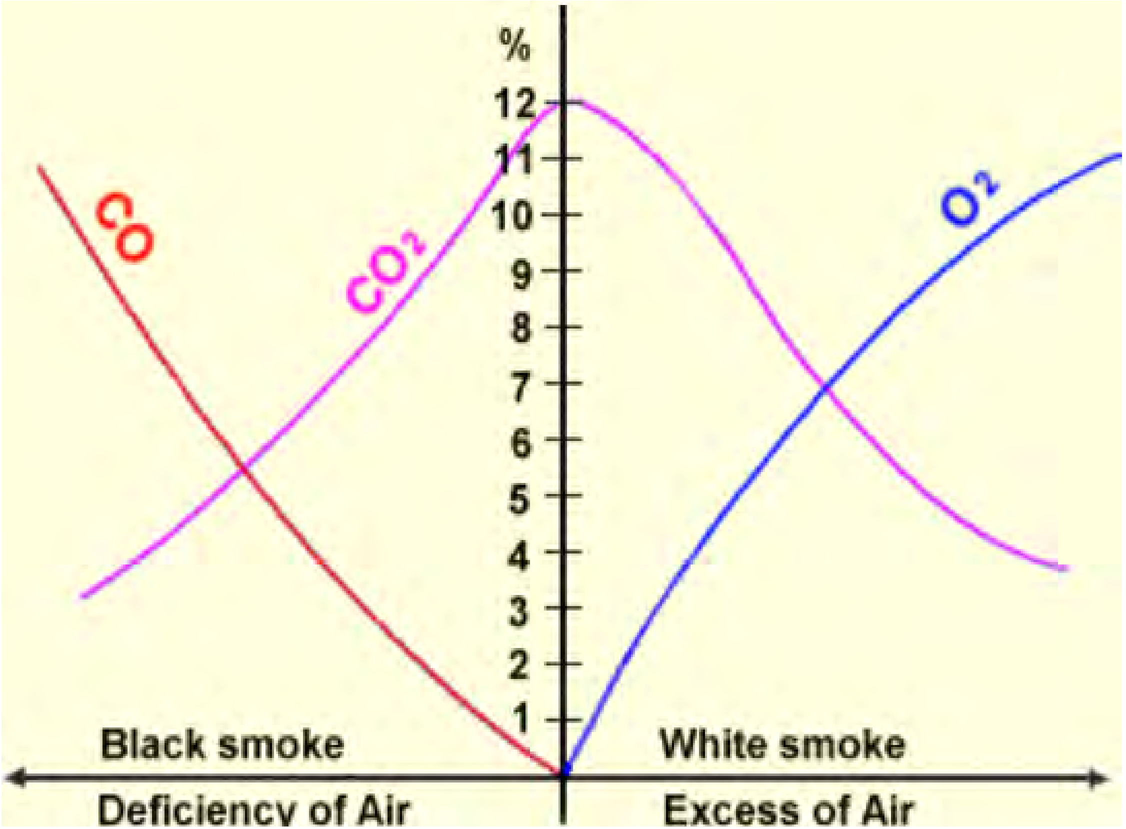
KTDA Target for thermal Energy Efficiency

- 300 Kg.MT/m3
- 3.5 – 4 Kg.Steam / Kg.MT (drying alone)
- Boiler Efficiency: 1800 Kg. steam/m3- Firewood boiler
- Boiler Efficiency : 14 Kg. Steam/ ltr.- F.O boiler
- 18.79 MJ/Kg.MT – Steam energy
- 1.98 MJ/Kg MT – Electrical energy
- 95% condensate recovery percentage

The combustion theory

- ◊Solid fuels (coal, wood & agro-waste briquettes) have a mixture of carbon, hydrogen, Sulphur and non-combustible substances like nitrogen, water and minerals
- ◊The best quality of solid fuel contains **90% C,H2** and a small amount of nitrogen, Sulphur and moisture
- ◊Air contains 21% O_2 + 79%N_2 *(neglecting other minor constituents)*
- ◊With complete combustion the C, S & H_2 are oxidized to CO_2, SO_2, H_2O & CO

Combustion Theory



- **CO** production in a boiler should be avoided at all times since increased CO gives a sharp rise in heat-loss besides air pollution
- Correct fuel to **air ratio** is essential to provide an **efficient** combustion. **Less** air mean **insufficient** oxygen available to burn all the fuel.
- With **excess air**, fuel is used up to heat the excess air from boiler-room temperature to the funnel temperature.

Boiler Combustion

- Depending on the amount of fuel fed into the furnace and the moisture content of the said fuel, the air required in the furnace to achieve a complete combustion is vital
- The optimum excess air level varies with furnace design, type of burner, fuel and process variables. For FO– 5-10% excess air and Firewood – 20-25% excess air
- Most Boilers have both ID and FD fans. The ID fan will induce a negative draft in the furnace thus draws out the burnt gases (Flue gas) whereas the FD fan will force in oxygen rich atmospheric air into the furnace to enhance combustion.

Boiler combustion

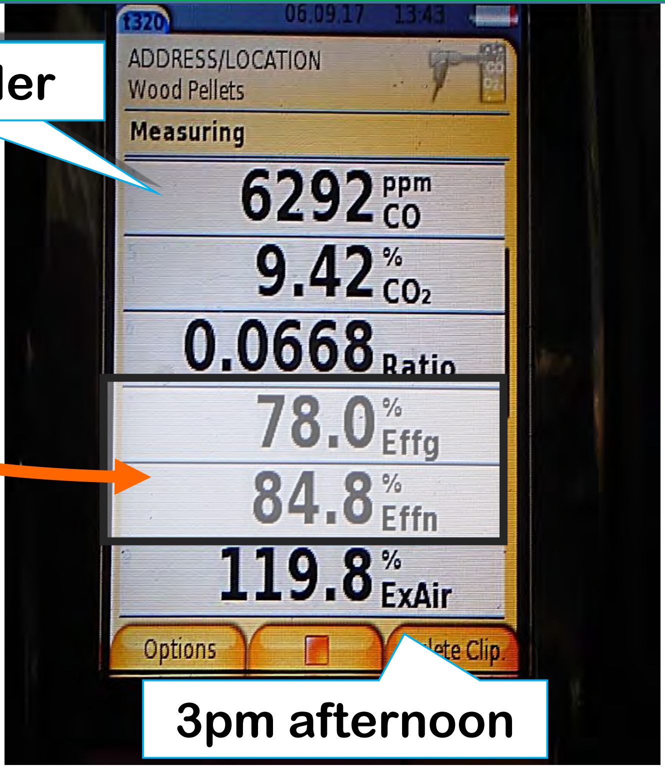
Air Fuel Ratio

- ❖Forced draught (FD) fan: provides combustion air (O2).
- ❖Induced draught (ID) fan: -ve draft to draw out products of combustion.
- ❖Air damper setting: Correct position for optimal combustion efficiency.

Effect of back pressure on combustion

Boiler combustion efficiency

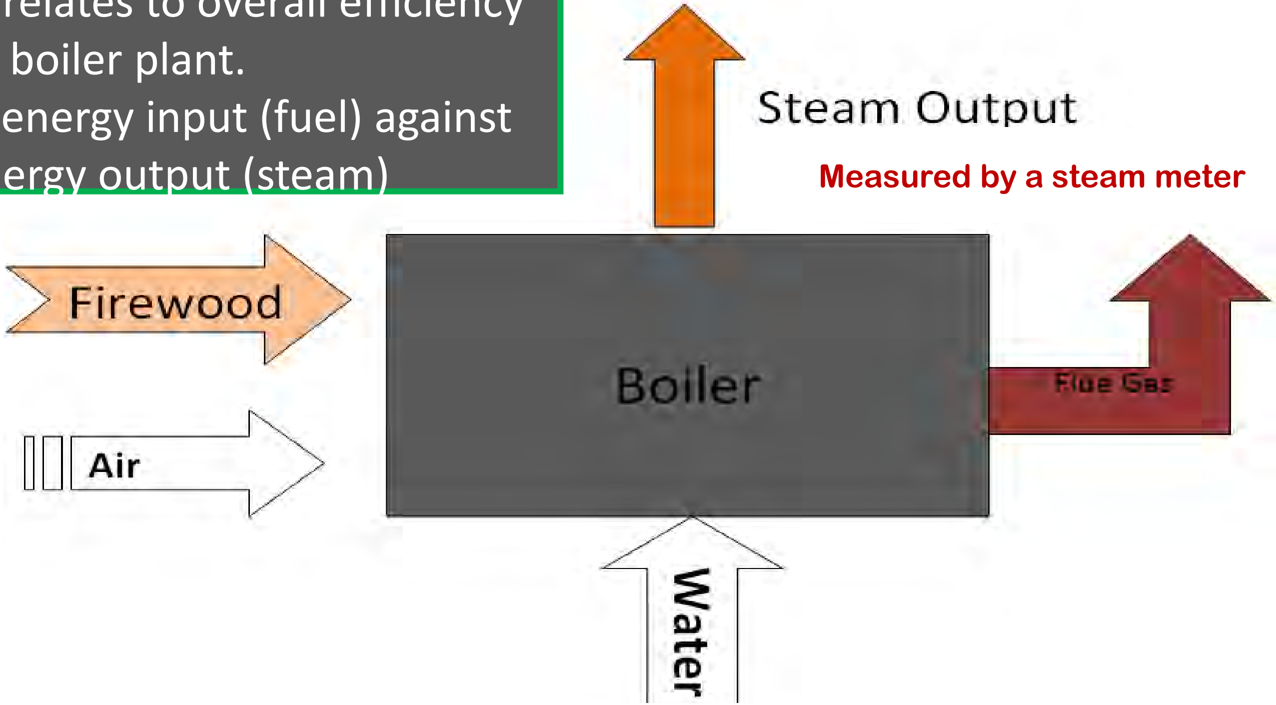
- ❖ Combustion efficiency is an indication of the burners ability to burn fuel
- ❖ Measured directly by a combustion analyzer



Boiler Efficiency

- Boiler efficiency relates to overall efficiency of boiler plant.
- Compares total energy input (fuel) against usable energy output (steam)

Measured 1m3 box

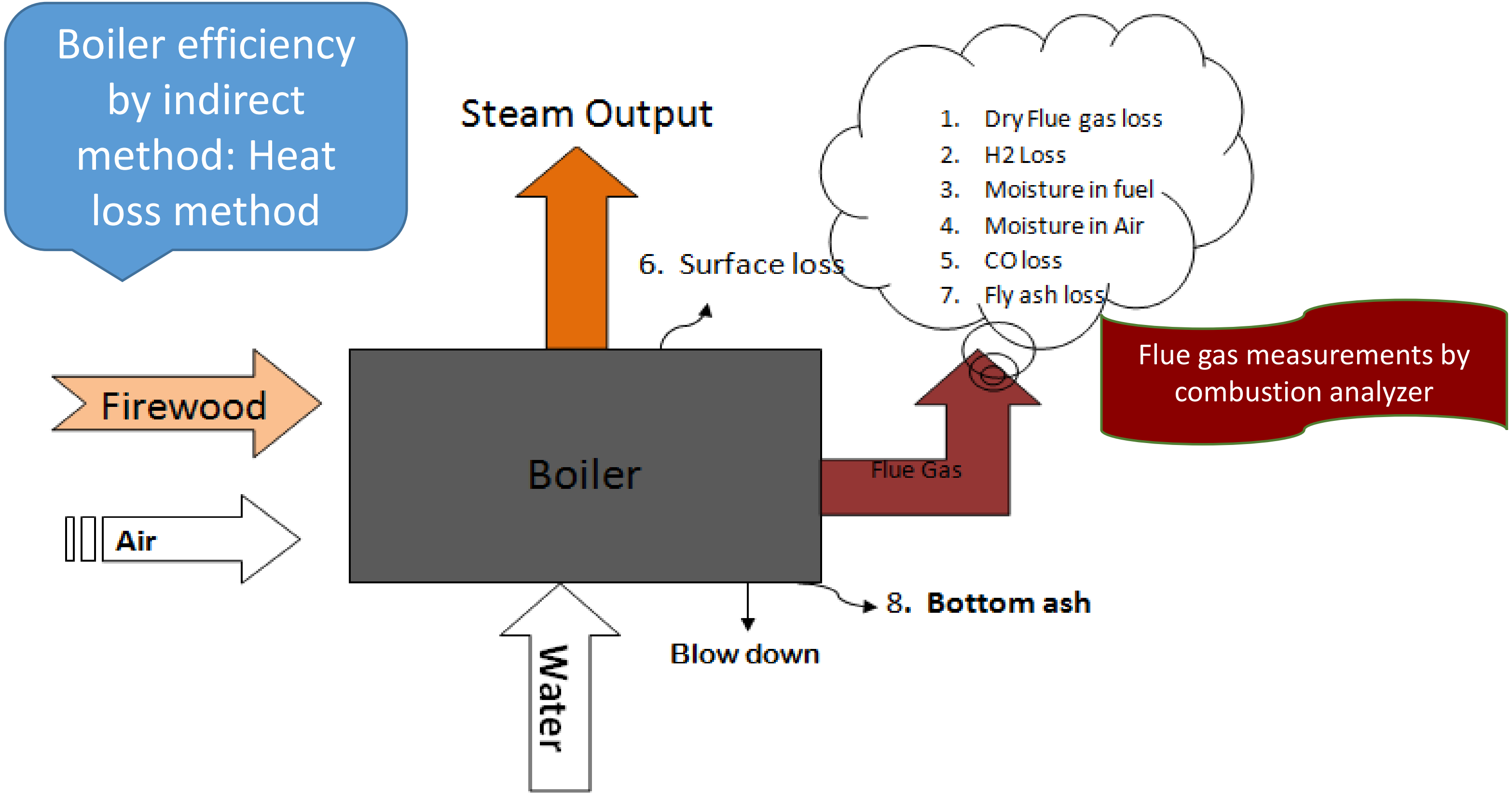


Measured by a steam meter

Direct method

$$\eta = \frac{Steam\ flow\ rate\ \left(\frac{Kg}{hr}\right) \times \{Steam\ enthalpy \left(\frac{MJ}{Kg}\right) - feed\ water\ enthalpy\ \left(\frac{MJ}{Kg}\right)\}}{Fuel\ firing\ rated\ \left(\frac{kg}{hr}\right) \times GCV \left(\frac{MJ}{Kg}\right)} \times 100$$

Boiler Efficiency



Boiler efficiency by indirect method: 100-L1+L2+L3+L4+L5+L6+L7+L8

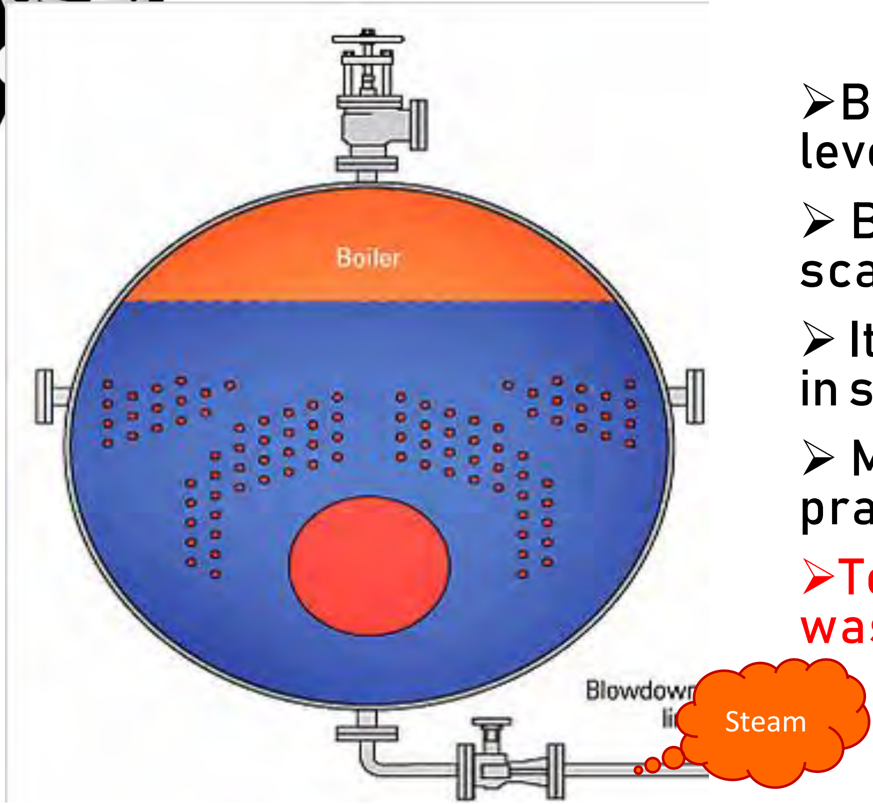
Feed and makeup water metering

- Feed water meter used to estimate steam generation i.e. if the FW reading is 4m3/hr. then steam generation is 4000 Kgs per Hour
- Boiler efficiency can be calculated as steam generated / m3. firewood
- Target efficiency-1800 Kg. Steam/m3
- Make up water metering allow for system losses analysis
- **Condensate Recovery (%) =** $\left(\frac{FW-MW}{FW}\right) \times 100$
- Target condensate recovery-95% by minimizing steam and condensate leaks.

Boiler water treatment-make up water

- It is critical that Boiler make up water goes through all the steps of water treatment: *Coagulation; Sedimentation; Filtration (up to 50ppm) then softening.*
- *Maintain water hardness at less than 1.0 ppm*
- Only softened water should be used as makeup to the condensate in the feed tank

Boiler water treatment- boiler blow down



Reasons for Boiler Blow down

- Blow down keeps the boiler water TDS level under permissible limits.
- Blow down prevents corrosion and scale formation in boiler tubes.
- It prevents the carryover of contaminants in steam
- Manual boiler blow down currently practiced in KTDA factories.
- Too much blow down can lead to energy wastage.

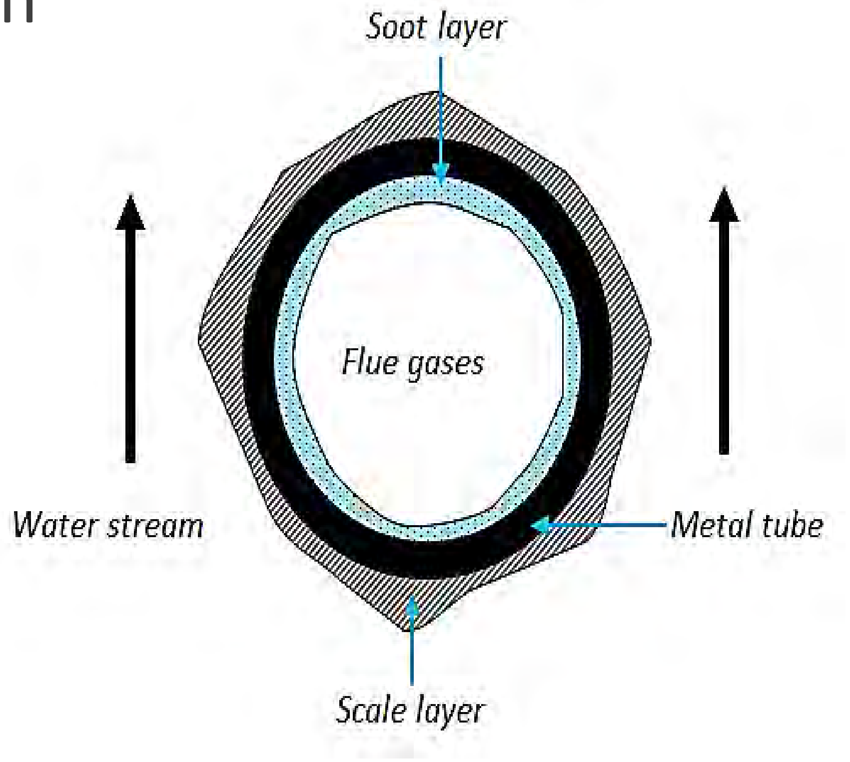
For the smoke tube boilers at 10.5 bars, the maximum allowable TDS in boiler water is between 3000-3500 ppm.

Soot and scales on boiler tubes

- Scales and Soot insulates the tubes and inhibit heat transfer leading to energy loss through the flue gas.
- Thermal conductivity of scale is about 1/100 of that of steel.
- Scales forms on the water side of a fire-tube boiler – ***Control Method:*** Boiler water treatment and De-scale
- Soot forms inside the tubes of a fire-tube boiler – ***Control method***: Weekly cleaning.

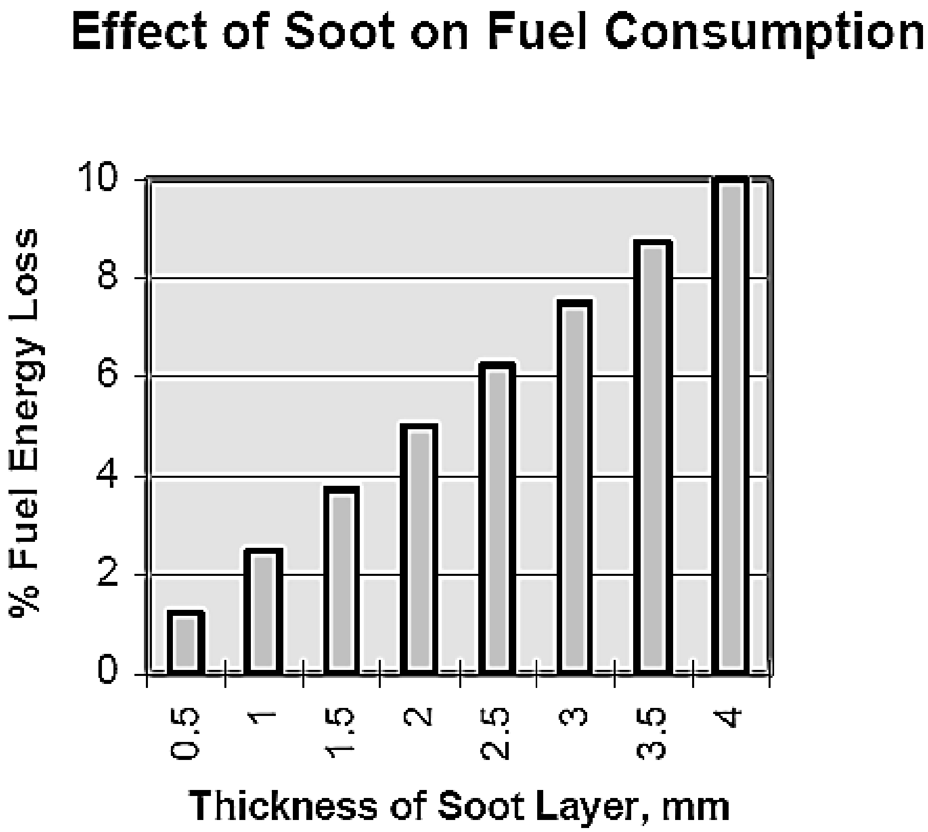
Effects of Soot and scales on boiler tubes

- More firewood consumption
- Tubes become distorted or deformed due overheating
- Life of equipment reduced
- Tube replacement cost
- Production loss: Drying and withering process



Soot and scales on boiler tubes

A poorly cleaned boiler with a soot layer of 2mm thickness consuming 2000m³ per month loses 5% on energy i.e. about 100m³ (appr. KSh 220,000) of the firewood as a result of boiler tubes fouling. When combined with scaling losses due to poor water treatment, the loss is even higher.



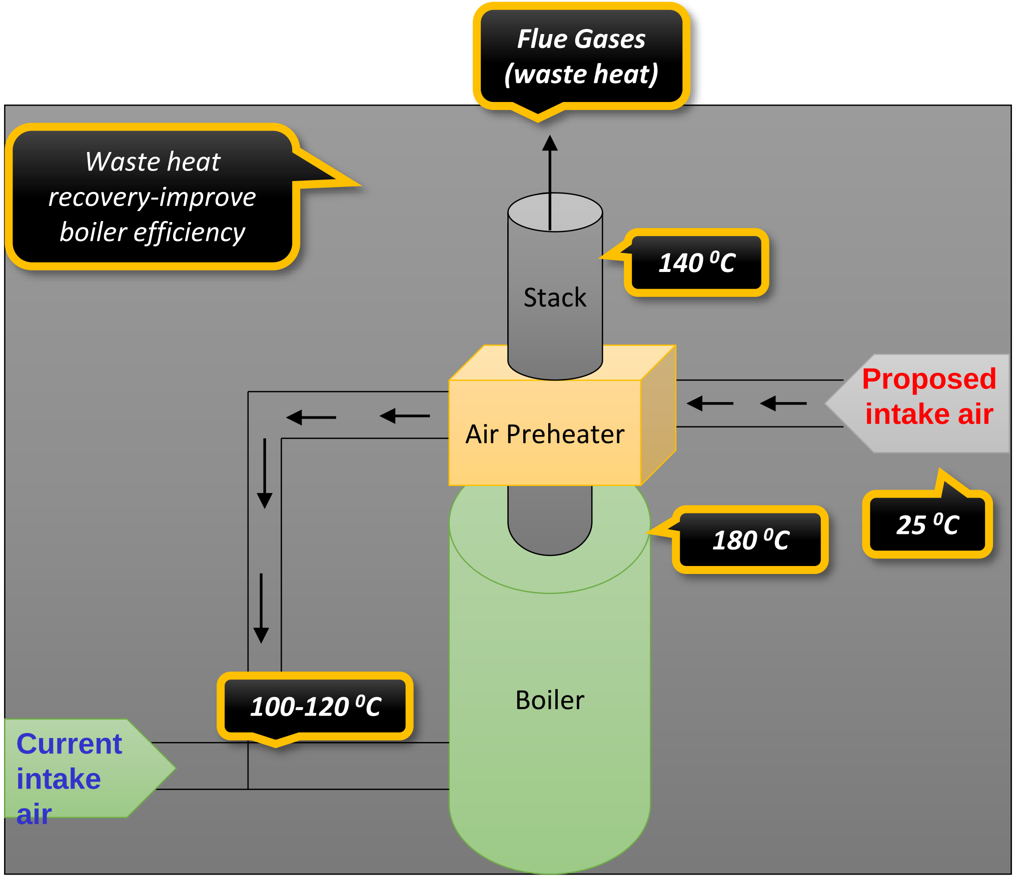
Boiler tubes cleaning

- Done weekly as part of boiler maintenance.
- All tubes should be cleaned to remove soot
- Clean from one end to the other.
- Use correct brush size

Air pre-heater (APH)

Raising the combustion air temperature by 20°C improves the boiler thermal efficiency by 1%.

Air pre-heater



- ❖Flue gases from the Boiler furnace at a temperature of about **180⁰C** passes through flue tubes and air at ambient temperature of **25⁰C** is forced over the tubes by the FD Fan. Heat from the flue gases is transferred through the tubes walls to the fresh air
- ❖The temperature of the fresh air rises upto **120⁰C** which is highly suitable for combustion thus improving the boiler efficiency.
- ❖Air pre-heaters should be designed to allow for external cleaning of tubes and ash removal.

Air pre-heater…case study

ITEM	DESCRIPTION	UNIT	Factory 1	Factory 2	Factory 3	Factory 4	Factory 7	Factory 6	Factory 8
	APH Installed		yes	yes	yes	yes	yes	no	no
Ta	Ambient Air temperature	˚C	22.2	20.3	12.9	20.9	20.2	20.3	16.8
Tf	Flue gas temperature	˚C	126	103.8	143.3	164	125.4	178.6	184.05
O2	Oxygen in flue gas	%	10.8	9.0	9.2	8.7	8.1	9.5	10.6
Ax	% Excess air	%	106%	75.0%	77.2%	70.7%	62.2%	81.8%	101.9%
Lf	Heat loss (dry flue gas)	%	6.6%	4.5%	7.1%	7.5%	5.3%	8.9%	10.4%
Lh	Heat loss (Steam in flue gas)	%	7.6%	7.4%	7.9%	7.9%	7.6%	8.1%	8.2%
Mw	Moisture content of wood fuel	%	22%	22%	25%	35%	19%	21%	24%
Lw	Heat loss due to moisture in fuel	%	3.07%	3.07%	3.63%	5.18%	2.64%	3.09%	3.60%
Lr	Heat losses through radiation losses	%	1%	1%	1%	1%	1%	1%	1%
Eff	Gross Boiler efficiency	%	81.8%	84.0%	80.3%	78.3%	83.5%	78.9%	76.9%
LT	Total losses in Flue gas (Lf + Lh)	%	14.2%	11.9%	15.0%	15.5%	12.9%	17.0%	18.5%

Average efficiency without APH: 77.9%

Average efficiency with APH: 81.6%

Average boiler efficiency improvement with APH: 3.7%

Boiler Instrumentation & Safety

1. Safety valves

- The safety valves are located at the highest part of the steam side of the boiler and connected directly to the shell.
- They are designed to pop open at some set pressures and when both are open no steam pressure accumulation should be there.
- The safety valves can be tested by hand (by lifting the test lever) or by pressure (by bringing the boiler pressure up to the point it will pop. when testing by hand, make sure there is at least 75% of the popping pressure in the boiler.

2 . Water column gauge glass

- A water column gauge glass shows the water level in the boiler and should be set at the normal operating water level so that the lowest visible part of the gauge glass is 2-3 inches the highest heating surface. This is important because no matter how low the level goes, the boiler operator knows it is safe to add water to the boiler.
- It is very dangerous to add water to a boiler if there is no water visible in the gauge glass for it might cause a boiler collapse. At the bottom of the gauge glass there is a gauge glass blow down valve to be used to blow down any sludge or sediments.

3. Two- switch control Mobrey switches

- The two switch contacts are actuated by a single float
- One switch controls the feed pump – starts and stops the feed pump as the water level in the boiler falls or rises above the average water level (AWL).
- The other switch operate the illumination light, cuts out the burner when water level falls to 1st low level and energizes the alarm. It restarts the burner automatically once the normal water is restored.

4. Single- switch control Mobrey switch

- The switch is float-operated and its function is to switch the burner off when water level in the boiler falls to a dangerously low level (extra low water).
- The burner can only be manually restarted, at the control panel, when the water has risen to a safe level.

5. Bottom blow down valves

The bottom blow down is used so as to;

- Control high water level
- remove sludge and sediments in the boiler
- Control chemical concentrations in the boiler water.
- Dump a boiler for cleaning or inspection.

6. Air cock

- Air cock is used to vent the air from the boiler when being filled with water
- Air cock allows the air to escape during boiler warm-ups.
- Air cock prevents a vacuum from forming in the boiler when taking it out of service. The vacuum can pull the manholes covers in to the boiler if lose which can damage to the boiler.

7. Pressuretrols-pressure switches

- These are pressure switches used to turn the boiler on and off and controls it pressure operation range. The pressuretrol has two adjustment screws and two scales. one scale is the cut-in and the other is the differential.
- It is important that pressuretrols are protected with a siphon to provide the water trap between the boiler and the pressuretrol.

8. Fusible plug

- Fusible plug is the last warning a boiler operator has of low water condition before he starts burning the tubes.
- This is a brass or bronze with a tapered, hollow centre that is filled with tin metal which melts at about 230^{o}C. It is located about 2’’ above the highest heating surface in the direct path of the gases of combustion.
- The tin does not melt as long as there is water in contact with the fusible plug to keep it cool. Fusible plugs must be kept clean both fireside and waterside. If scale was to build up, water will not cool the plug and hence would melt even when the water level was normal. Plugs must be replaced annually, this is because tin has a tendency to crystallise and this would increase its melting point.

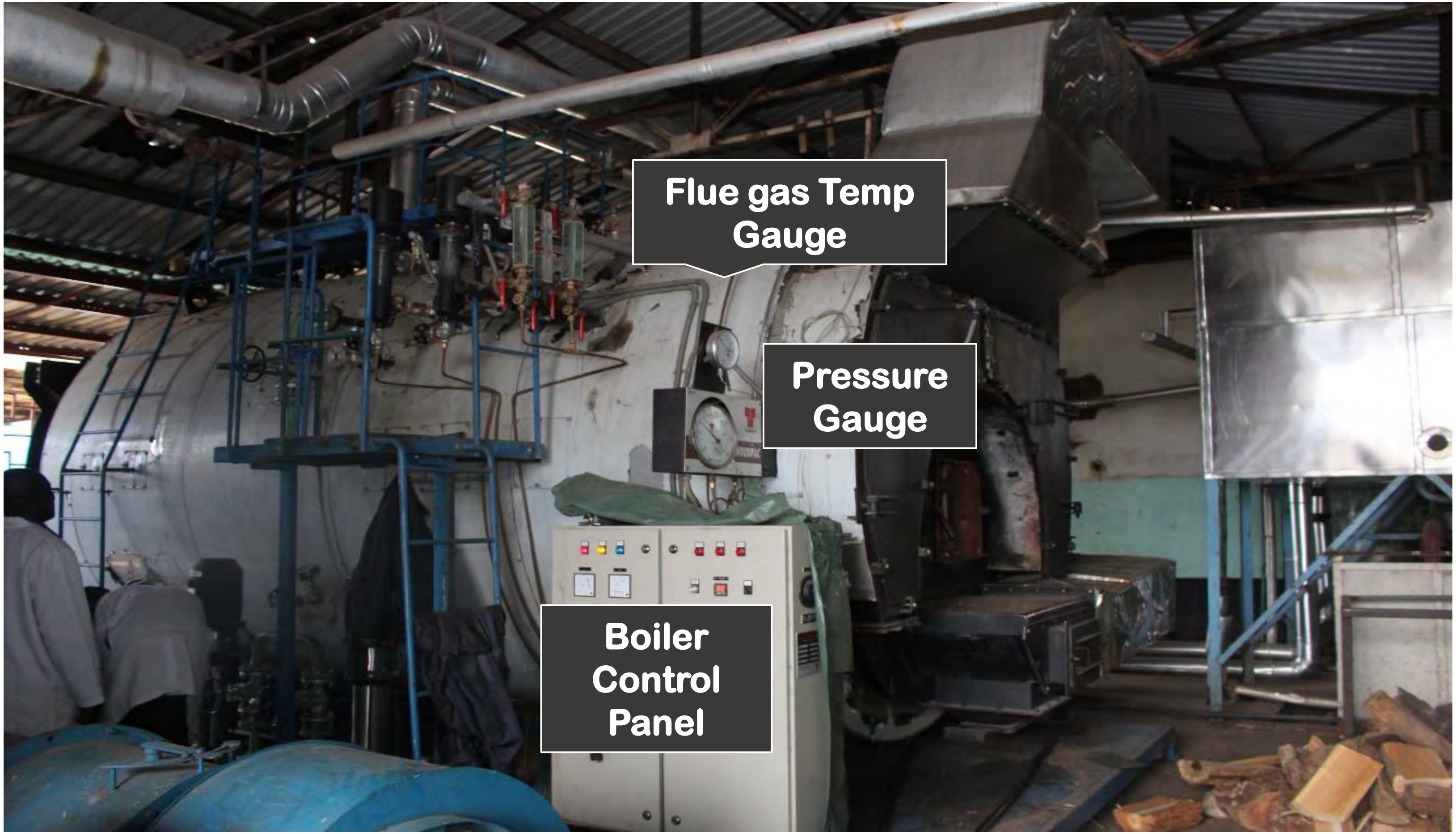
9. Pressure gauge

- The pressure gauge shows how much steam pressure is in the boiler. This allows the boiler operator to operate his boiler in safe operating range.
- The boiler pressure gauges are the Bourdon type and hence should be protected from steam entering the Bourdon type otherwise it will be damaged or will give false readings. To prevent this, siphons are installed between the boiler and the gauge. The range of the steam gauge should be 1 ½ to 2 times the MAWP (maximum allowable working pressure) of the boiler.

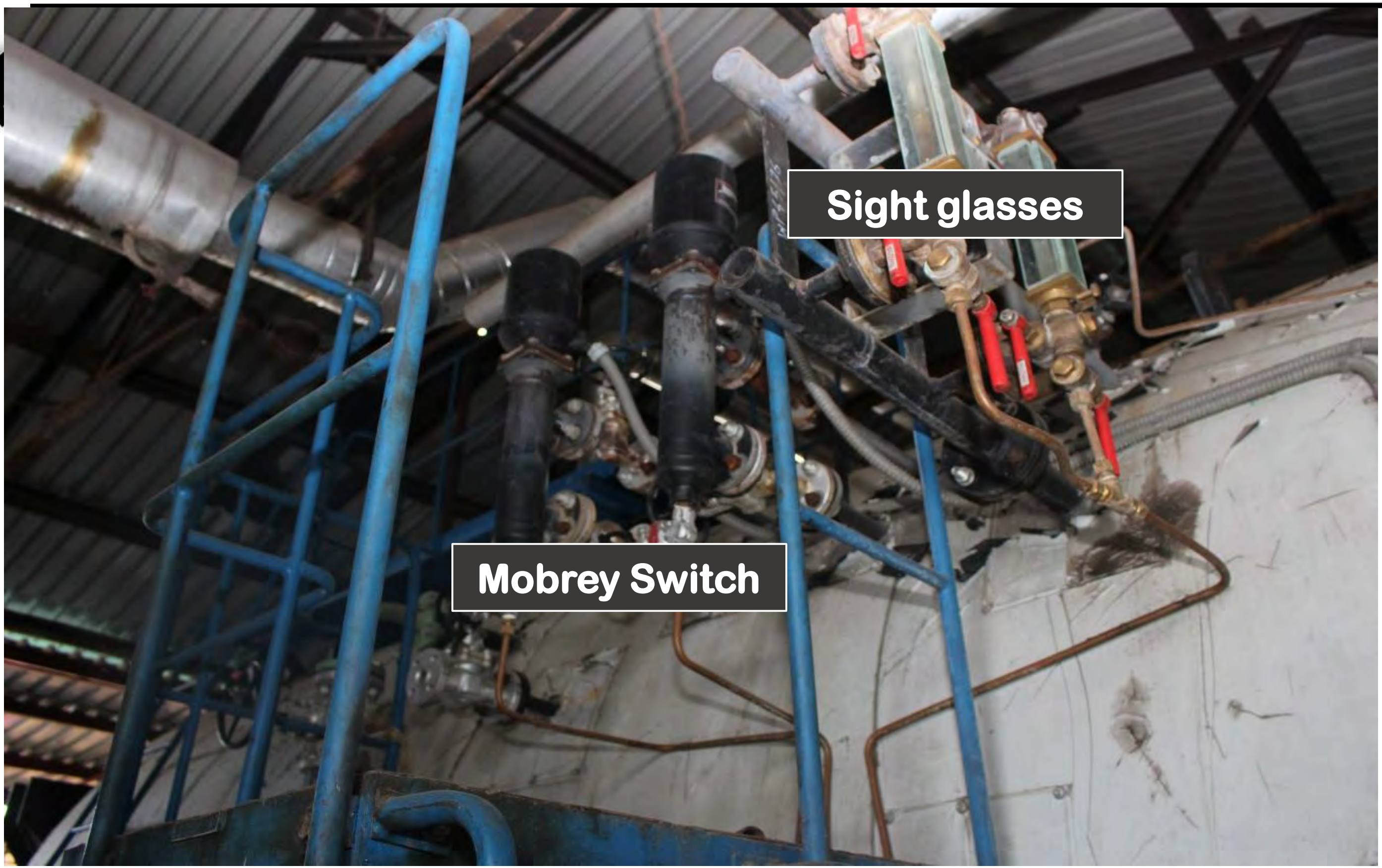
10. Temperature gauges

- **Feed water temperature gauge** – Measures the temp. of the boiler feed water; should be around **87^{0}C**. Higher temps are not good to feed pump and low are not good for boiler efficiencies.
- **Flue gas temperature gauge** – Measures the flue gas temp. as it exits the boiler. High temp readings means low boiler efficiencies and low temp. readings means incorrect probe location or defective gauge. The flue gas temp. should be between **185 – 200^{0}C** given than the steam saturation temp at **9 bars** is **180^{0}C.**
- **Combustion air (CA) temperature gauge-** measures the temp of preheated air as it exits the APH. Temperature normally between **100-120^{0}C.** Lower temps indicate reduced heat recovery in APH. If temp of combustion air after APH is almost equal or equal to ambient air then APH is not working.

Instrumentation & Safety



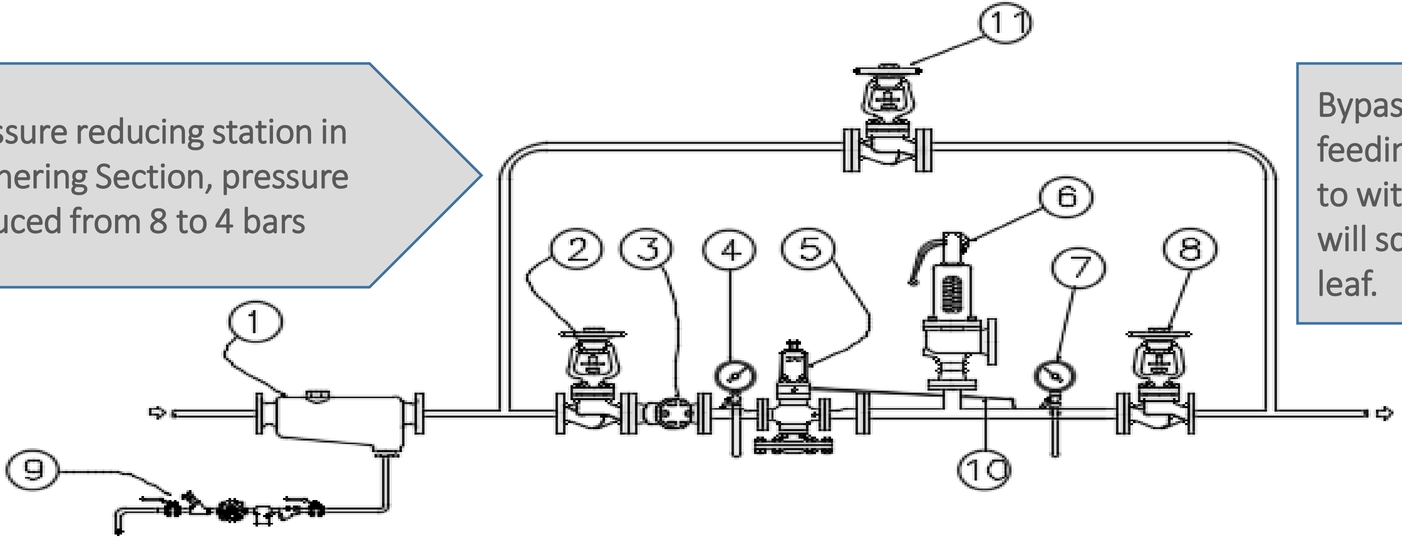
Instrumentation & Safety



Pressure Reducing Station

Pressure reducing station in Withering Section, pressure reduced from 8 to 4 bars

Bypassing PRS and feeding steam at 8 bar to withering trough will scorch withered leaf.



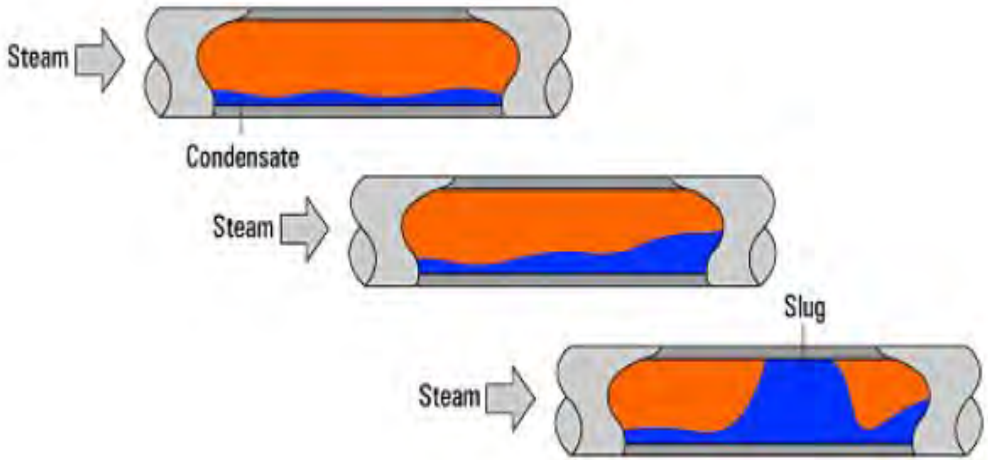
1. SEPARATOR = DN80
2. ISOLATING VALVE = DN100
3. STRAINER = DN80
4. DIAL PRESSURE GAUGE
5. PRESSURE REDUCING VALVE DN80 with pilot sensing line.
6. SAFETY VALVE = DN50 Set at 4 Bar g.
7. DIAL PRESSURE GAUGE
8. ISOLATING VALVE = DN100
9. TRAPPING STATION = DN25
10. BALANCING PIPE
11. ISOLATING VALVE = DN 50

Why remove air and condensate from steam

- Improve heat transfer efficiency – Air and water (condensate) prevent efficient heat transfer across radiator walls
- Prevent corrosion – air has oxygen which corrodes steel pipes
- Prevent perforation and equipment wear – Water droplets in steam moving at high speed impinge on the inside of steam lines and fittings creating holes/leaks
- Prevent water hammer

Water Hammer in steam lines

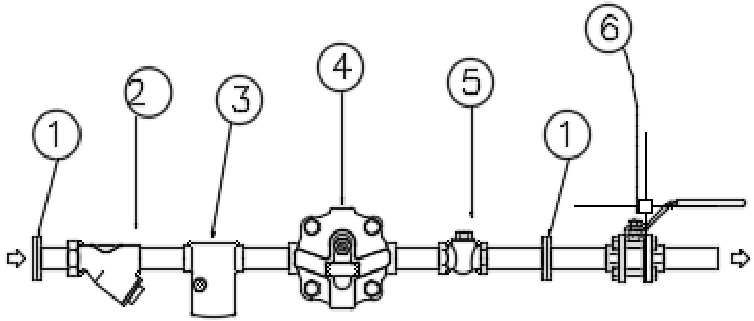
- Common during start up – if main valves are opened rapidly
- Occurs if condensate draining is not effective, failed traps, upward inclining lines



Steam Traps

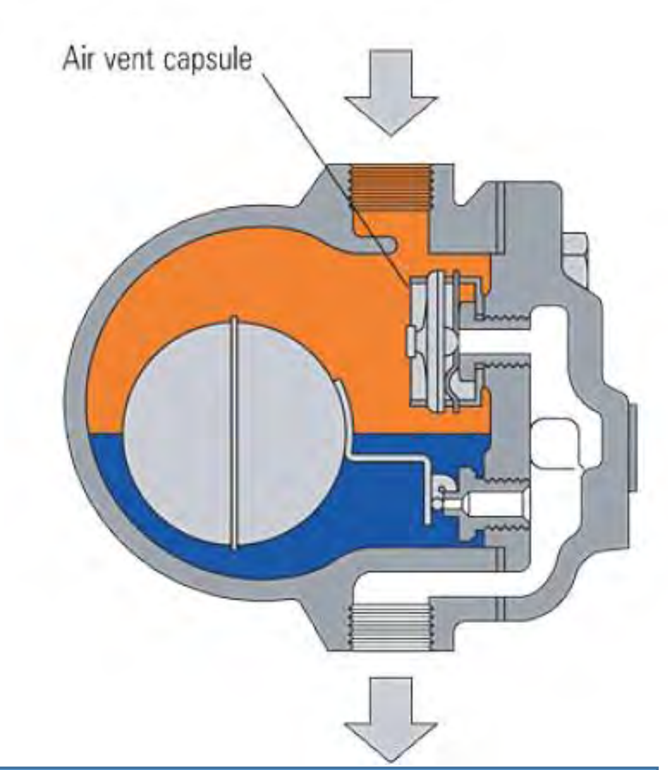
- Steam traps are automatic valves which close in steam but open to discharge condensate and air in the system that would cause barrier to heat transfer
- Steam radiators receive steam from one point but have the same steam stopped from going out at the other end by a steam trap
- They achieve this either mechanically using float ball traps and inverted bucket traps or thermostatically or thermodynamically or venturi principles.

Steam Traps



1. MATCHING PAIR OF STEAM FLANGES DN 15
2. STRAINER DN15
3. SENSOR CHAMBER DN 15
4. STEAM TRAP DN 15
5. CHECK VALVE DN 15
6. ISOLATING VALVE DN15

Steam fittings arrangement



Standard float ball steam trap

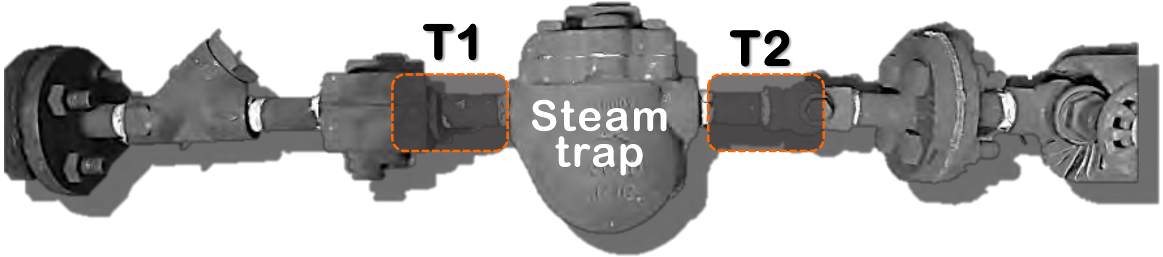
Steam traps failure

Steam Trap Failed OPEN and passing Steam in Ogden Pumps

- When a steam trap fails in an **open position**, it allows steam to pass **through**. The equipment e.g drier will continue to function normally but its steam consumption will increase.
- The overall effect is increased energy cost as more firewood is consumed in the boilers for the additional steam generation.
- When a steam trap fails in a **closed position**, the radiator will get **flooded** since there will be no discharge of condensate hence minimal heat transfer across the radiator. This will negatively affect the equipment performance.

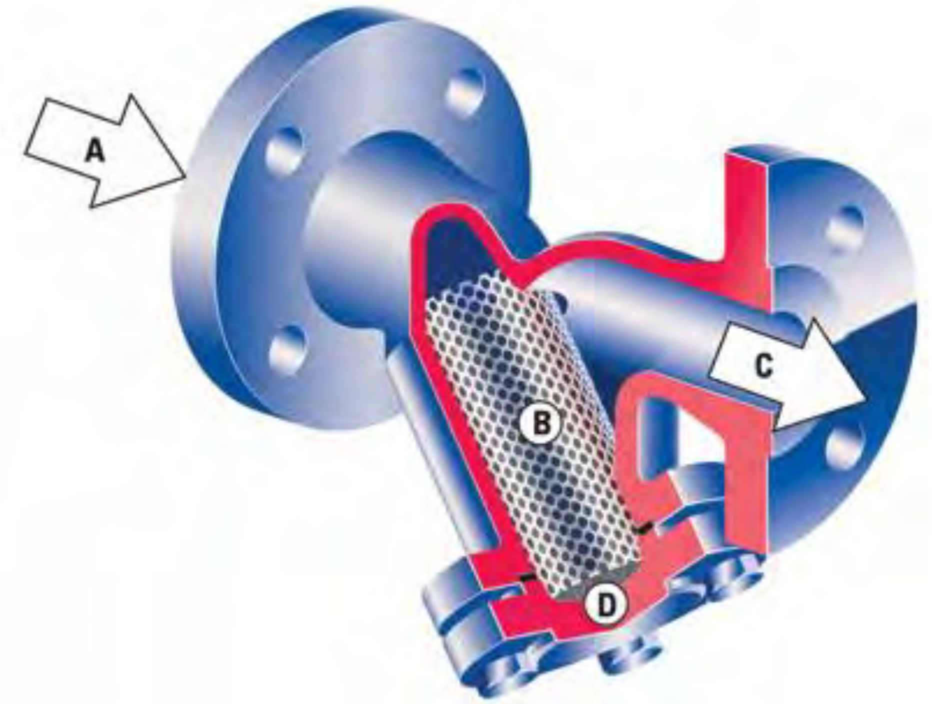
Steam trap checking

An infra-red thermometer can be used to test if steam trap is functioning normally by taking upstream and downstream temperatures.



Upstream	Downstream	Status
Temp [T1]	Temp [T2]	
140 ^{0}C	110 ^{0}C	Functioning Well
140 ^{0}C	140 ^{0}C	Failed Open
60^{0}C	50 ^{0}C	Failed Closed

Strainers



Worn-out strainer

Strainer with particles

- Strainers trap particles in the steam line from reaching the steam trap and damage or block the condensate discharge ports
- Strainers should be cleared of trapped particles once or twice a year

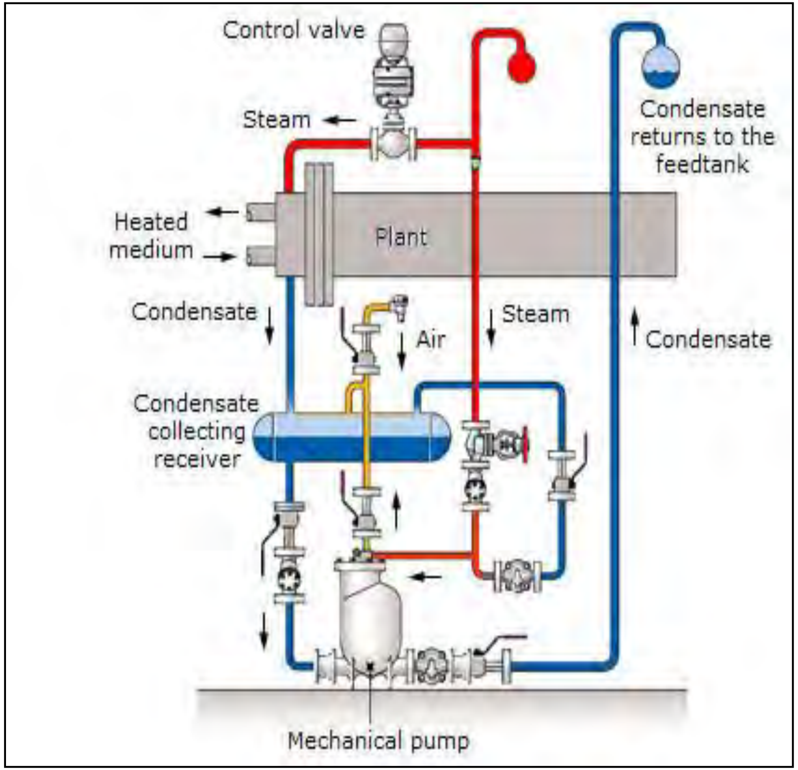
Steam and condensate leaks.

- Steam and condensate leaks through failed steam trap, valve or through an orifice/hole on the piping leads to valuable heat loss
- Consider a steam leak of 0.5 Kg/min in a pipe supplying a steam radiator in the dryer . Assuming daily running time of 16 hrs. and annual running time of 300 days. Annual steam loss is 144,000 Kgs.
- Efficiency of KTDA biomass boiler 1800 Kg.steam/m3. Therefore, firewood used to generate 144,000 Kgs of steam is 80m3
- Firewood cost is Kshs 160,000 per Annum.

Ogden pump

Ensure that all condensate is evacuated by the Ogden pump(s) so that the feed water temperature can be kept as high as **practical (87^{0}C)** to improve plant efficiency

Ogden pump

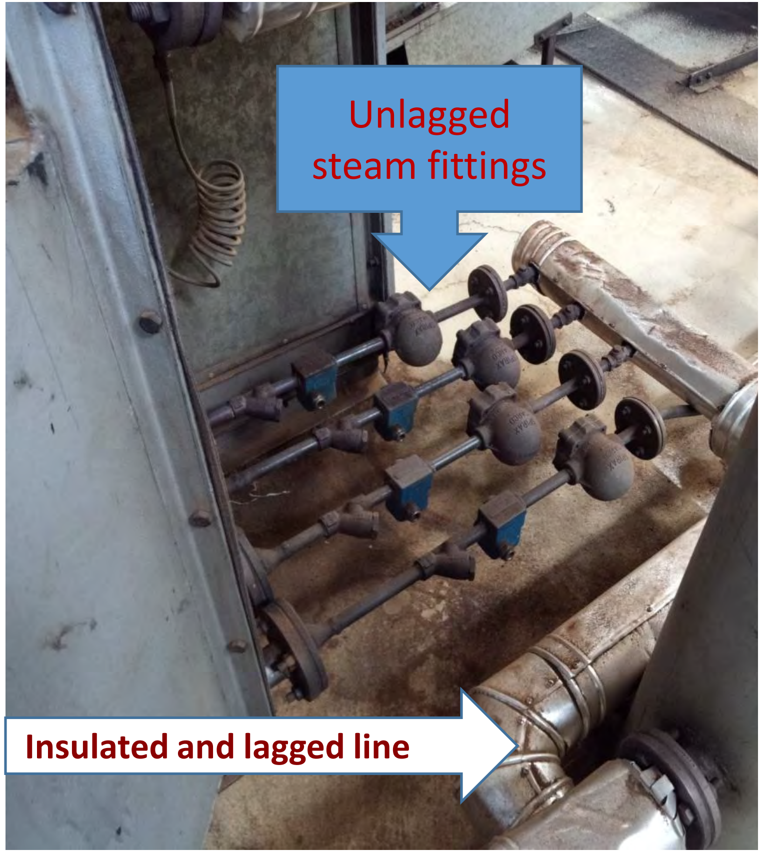


- ❖ Ogden pumps are mechanical (steam powered)

OGDEN PUMP WEEKLY MAINTENANCE SCHEDULE

1. Checking whether the pump has an overflow and repair the pump if found.
2. Checking the condition of the exhaust steam for the Ogden breather, if a lot of steam plume is found investigate the pump for failure and main steam traps and repair/replace accordingly.
3. Checking for water and steam leakages and investigate cause and rectify appropriately.
4. Test the Ogden drain steam trap for faulty and if faulty repair/replace appropriately.

Heat Loss Management



- **Why insulate?**
- Un-insulated surfaces means loss of energy and risk of injury from burns and heat shock to workers
- Insulation is done on boiler surfaces, steam and condensate lines, steam fittings, condensate tanks and APHs

Insulation of Steam and Condensate System

- Insulation must be done in all hot surfaces- If you can't touch, insulate.
- Choice of insulating material is important: Insulating properties, thickness, non-contaminating and cost
- Mineral rock wool is commonly used
- Water logged insulation due to steam and condensate leaks in piping reduces its effectiveness
- Cladding material protect insulation and should be of low emissivity (reflective)

Lagging of steam lines

Table 2.12.4 Heat emission from unlagged steel pipes freely exposed in air at 20°C (W/m)

Temperature differential steam to air °C	Pipe size (mm)									
	15	20	25	32	40	50	65	80	100	150
50	56	68	82	100	113	136	168	191	241	332
60	69	85	102	125	140	170	208	238	298	412
70	84	102	124	152	170	206	252	289	360	500
80	100	122	148	180	202	245	299	343	428	594
100	135	164	199	243	272	330	403	464	577	804
120	173	210	256	313	351	426	522	600	746	1 042
140	216	262	319	391	439	533	653	751	936	1 308
160	263	319	389	476	535	651	799	918	1 145	1 603
180	313	381	464	569	640	780	958	1 100	1 374	1 925
200	368	448	546	670	754	919	1 131	1 297	1 623	2 276
220	427	520	634	778	877	1 069	1 318	1 510	1 892	2 655

Lagging of steam lines

- Steam fittings can be converted to equivalent pipe lengths (m)
- Consider a 2’’ (50mm) dia. uninsulated 10 m steel pipe carrying steam at 4 bar in the withering section.
- Surface temp 140˚C, ambient temp 20˚C. Temp difference 120˚C.
- Heat loss on exposed pipework-426 W/m. For 10 m pipe length the total heat loss is 4.26 kW. Assuming daily withering section is 16 hr. and annual running time is 300 days, annual energy loss is 20,448 kWh (73,612.8 MJ).
- Enthalpy of steam -2.03 MJ/Kg. Equivalent steam loss -36,262.46 Kgs
- Efficiency of boiler 1800 Kgs. Steam/m3. Therefore, equivalent firewood consumption 20m3.
- Annual energy cost- firewood is Kshs 40,000

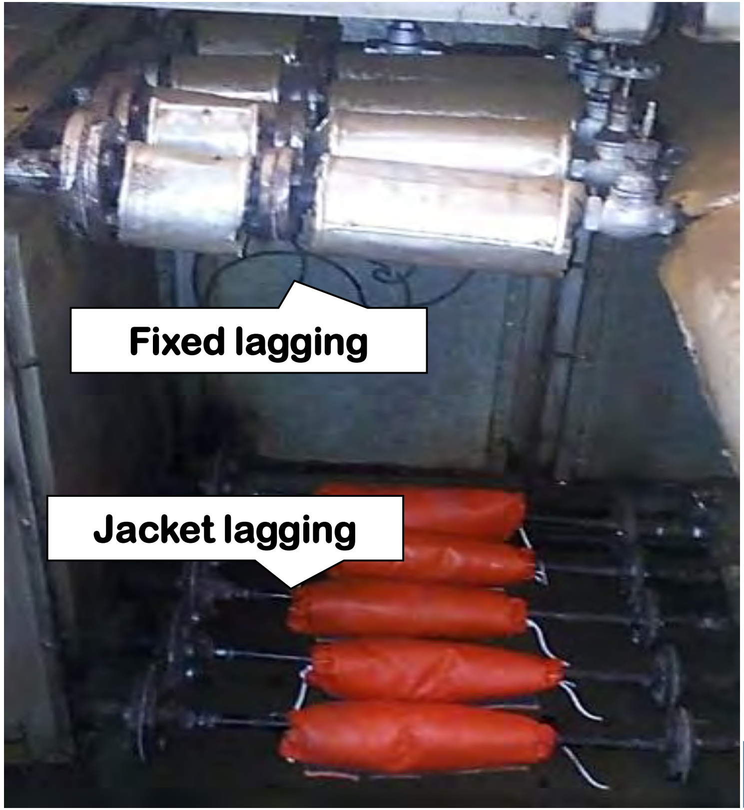
Bad cases of lagging and cladding

Failed insulation and cladding in feed water tank

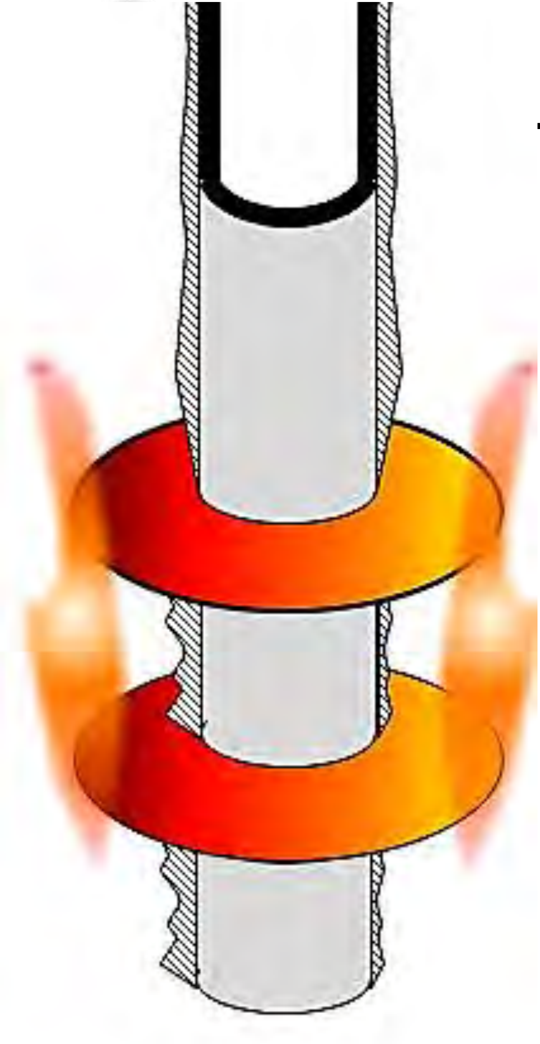
Unlagged steam fittings in drier radiator

Unlagged steam piping in drier

Best practices in lagging and cladding of steam system



Removable box with lagging (Kambaa T. Factory



Steam radiators

- A heat exchanger in which hot steam is held in the tubes whereas cold air is forced externally over the tubes which have fins on the outer surface to delay the cold air movement.
- Steam enters the radiator tubes on one end and is stopped from getting out by the steam traps on the other end.

Steam radiators

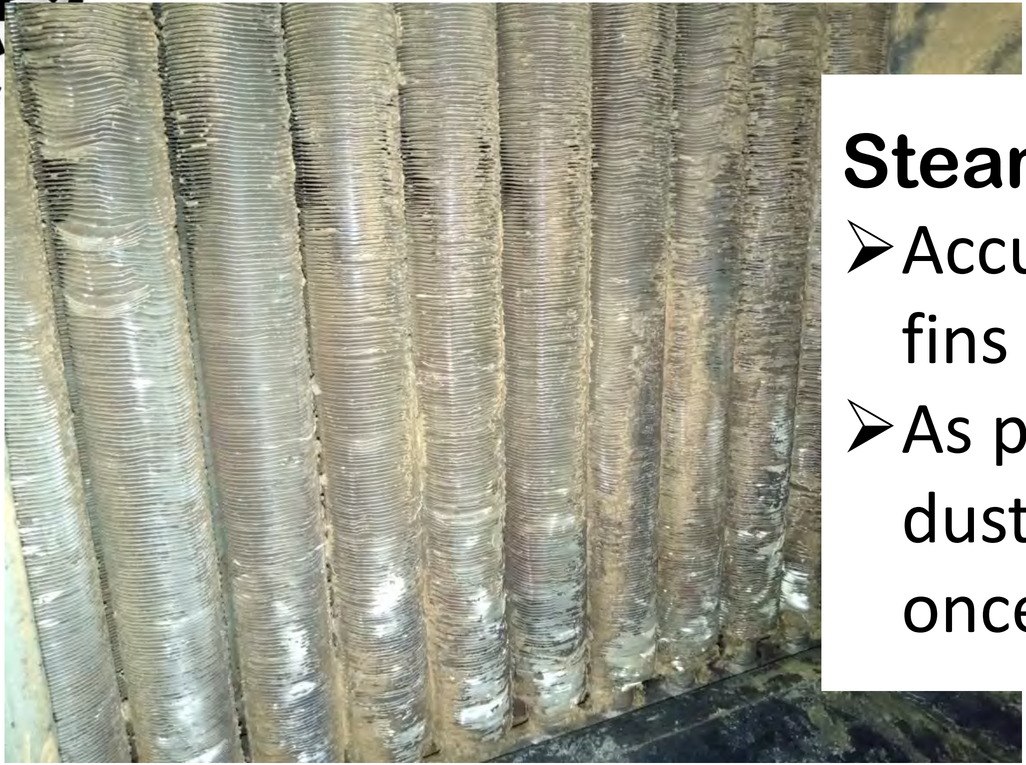
- Flooded radiator is at risk during system start up when live steam picks condensate in the system carrying it like a stone. When it gets to a bend or a valve, it hammers the bend and courses breakages leading to leakage
- Trapped air act as an insulator thus heat transfer is affected.
- The steam traps installed need to be able to evacuate condensate and non-condensable gases

Steam radiators

- Heat transfer is reduced in a corroded, leaking and dust covered steam radiator
- Reduced heat transfer results in increased steam and firewood consumption
- End process affected- Longer drying and withering time

Corroded steam radiator in withering

Steam radiators



Steam radiator in drier

- Accumulation of dust in fins reduces heat transfer
- As part of maintenance, dust should be blown off once per month

Boiler Records

- Key boiler performance parameters to be recorded include firewood consumption (m^3), feed water consumption (m^3), boiler pressure (bars), flue gas temp (ºC), combustion air temp before and after APH (ºC), Feed water temperature (ºC), boiler running time (hrs).
- Boiler operator should maintain accurate and up to date records.
- Analyse key thermal system KPIs; boiler efficiency in Kgs of steam/m3, firewood utilisation in Kg.MT/m3.

MOD 4: Production Floor Machinery O & M.

- ❖ Mechanical systems in the production floor include monorail, withering fans, dampers and louvres, withering troughs conveyors, CTC machines, humidifiers, driers, sorters, bulking bins, winnower.
- ❖ Breakdown and downtime in these systems / machines affect throughput and as a result production time is increased SAME AS ENERGY.
- ❖ Plant technicians, mechanics and boiler operators play an important role in operation and maintenance of these systems.
- ❖ Properly and adequately maintained systems are energy efficient.
- ❖ Maintenance can be: preventive, corrective and reactive (breakdown).

Common Machinery Breakdown that affect energy efficiency

- Unbalanced vibrating fans: *Lowers airflow (CFM), increased withering time results in higher electricity and firewood cost*
- Leaking troughs, transition pieces: *Lowers airflow, increased withering time results in higher electricity and firewood cost.*
- Leaking steam radiators: *Increase in steam and firewood consumption in the drier and withering section*
- Hot air leaks: *Increase in steam and firewood consumption in drier and withering section*
- Unsecured (loose) dampers / louvres: *Loose dampers can close and lower airflow to withering troughs.*
- Misaligned rollers in CTC: *Lowers throughput, increased electricity consumption*

Common Machinery Breakdown that affect energy efficiency

- Missing scrappers in CTC: *Spillages lowers throughput, increased electricity consumption and cost*
- Over meshed rollers in CTC*: High pressures, increased electricity consumption, affects quality of products.*
- Incorrect sharpened rollers in CTC: *Affects quality of made teas. Additional electricity and steam consumed during rework.*
- Misaligned discharge conveyors: *Spillages lowers throughput, increased energy consumption and cost*
- Worn-out conveyors belts- *Spillages lowers throughput, increased electricity and firewood consumption and cost*

Common Machinery Breakdown that affect energy efficiency

Spillages due to missing scrappers in CTC rollers affects throughput

Misaligned conveyor divider lowers throughput in CFU

Common Machinery Breakdown that affect energy efficiency

Worn-out conveyors affects throughput

Spillages of fermented teas due to misalignment of conveyors

Going Forward

- ❖ Reduce machine breakdown and downtime to realize energy savings.
- ❖ Maintenance procedures to follow KTDA maintenance manual.
- ❖Discuss in details with team on sectional preventive maintenance program done on Mondays i.e. Withering, CTC, CFU, Drying, Sorting and Packing

Preventive maintenance on CTC rollers. Done every Monday

MOD 5: Health and safety – Good Practices

- PPE Personal Protective Equipment: Ear muffs, safety goggles, hard hut, dust mask, safety boots.
- Safe Working Environment: Fixing steam leaks, hot air leaks , insulation of hot surfaces and ergonomics.

Health and safety – Bad Practices

Bad Housekeeping in Boiler House

NO PPE; wearing flip flops while splitting firewood

ENERGY SAVED

IS

ENERGY GENERATED.

THANK YOU.

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Ethical Tea Partnership

KTDA
Kenya Tea Development Agency Holdings Ltd

Strathmore University
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